Intercontinental Geoinformation Days

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# 2D Flood modeling with the help of GIS: Mersin / Lamas River

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**Keywords**
Flood modeling
Mersin
Lamas River
HEC-RAS 2D
CBS

**ABSTRACT**

A flood is a natural disaster that causes damage to the surrounding lands, settlements and living creatures by not fitting the amount of water in the riverbed for various reasons. Flood disasters all over the world and second in terms of loss of life and property in Turkey, located between meteorological disasters in the first place. To reduce the material and moral damages of floods affecting our lives, it is necessary to know the mechanism that turns the flood into a disaster and to take precautions before the flood occurs. In this study, Lamas River Basin, where floods were experienced many times in the past, was chosen as the study area. 2D flood modeling was performed with Geographical Information Systems and HEC-RAS-2D program. As a result of the modeling, flood depth and propagation maps were obtained for different flood return periods ($Q_{50}$, $Q_{100}$ and $Q_{500}$).

## 1. INTRODUCTION

Flood is a natural disaster that interrupts economic and social activities in the region by damaging surrounding lands, settlements, infrastructure facilities, and living creatures, due to reasons such as excessive rainfall, rapid melting of the existing snow, landslide, uncontrolled water release from the dam, and by changing the cross-section of the riverbed. It ranks second among all disasters and first among meteorological disasters in terms of loss of life and property in the world and our country. When the current data are examined, the economic loss caused by the floods is approximately 300 million TL every year. When examining the flood events and effects that occurred in our country between 1975 and 2015; it was observed that 1209 floods occurred, 720 people lost their lives, and 893.993 hectares of land were submerged. The year when the most flood occurred was 2015 (122 times) and the most casualties were in 1995 with 164 people. The total number of floods experienced between 1975 and 2002 is 487, and the total loss of life is 493. The total number of floods evaluated in the 2003-2015 period was 722, and the total loss of life was 227 (DSI 2017).

The precipitation regime is changing with global warming and climate change. This situation causes precipitation to turn into natural disasters. Floods from natural disasters are not a problem that can be eliminated completely. Therefore, preventive measures should be taken against floods, especially in urban areas, upstream and downstream of rivers. Globally, there has been a growing interest in recent years to predict floods, manage impacts and mitigate associated damage. Reducing the damage caused by floods requires different strategies in different areas. Therefore, targets and measures used in flood risk management should be diversified and regionalized (Hooijer et al. 2004). The purpose of flood modeling and risk analysis is to minimize the loss of life and property caused by floods (Petrow et al. 2006). It is also the protection of river ecology (Rubinato et al. 2019). The nature of the flood hazard is often defined by causation, in other words the probability and magnitude of the flood event. Flood risk is a function of flood vulnerability (Merz et al. 2007). Rapid and unplanned urbanization, insufficient infrastructure systems and changes in precipitation characteristics due to climate change create more areas that will be affected by floods in our country and around the world (Willems et al. 2012). Losses of lives, injuries, psychological traumas and deterioration in social life occur in these areas due to floods. In addition, floods can cause damage to public and private properties, infrastructure systems such as sewerage and superstructure systems such as roads and bridges

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**Cite this study**

Demir V, Alptekin A, Çelik M. Ö, & Yakar M (2021). 2D flood modeling with the help of GIS: Mersin / Lamas River. 2nd Intercontinental Geoinformation Days (IGD), 175-178, Mersin, Turkey

(Demir and Ülke Keskin 2020) For these reasons, city planners should primarily assess the flood risk for new settlements.

The Hydrologic Engineering Centers River Analysis System (HEC-RAS) software is frequently used in flood modeling worldwide. Yazıcılar and Onder (1998), Tate et al. (2002), Sheffer et al. (2008) have used HEC-RAS software to map flood areas. In this study, the Lamas river flowing into the Mediterranean and situated in the Eastern Mediterranean Region of Turkey was designated as the work area. There have been many major floods in this area in the past. The last recorded floods occurred in January 1959, December 2001, and October 2006, and there were great financial and emotional damage in the floods. Therefore, this study aims to perform two-dimensional modeling of 50-, 100- and 500-years flood return periods of Lamas River with the help of the HEC-RAS program, which can work integrated with GIS systems and GIS systems and hydraulic calculations can be made.

## 2. MATERIAL and METHOD

### 2.1. Study Area

Mersin is located to the west of Adana, the southeast of Karaman the southwest of Niğde, the south of Konya and the east of Antalya. The surface area of Mersin province is 15.853 km$^2$. Except for 50% of the Tarsus district, all of it is within the boundaries of the Eastern Mediterranean Basin. Mersin province, which is surrounded by the Mediterranean in the south, is separated from the inner parts of Anatolia by the high plateaus and peaks of the West and Central Taurus Mountains from the north (URL 2021). Lamas River (Limonlu) is located in Erdemli district. This river takes its source from the Yüğlük Mountain in the region of Karaaydın. The Lamas River, which joins the Aksıfat River, flows into the Mediterranean from the Limonlu district (CVSB 2016; SYGM 2019). For this reason, the river gave its name to the Limonlu district. Its length is 99 km. The annual average flow rate is 6.25 m$^3$/s (SYGM 2019). The study area is included in Figure 1.

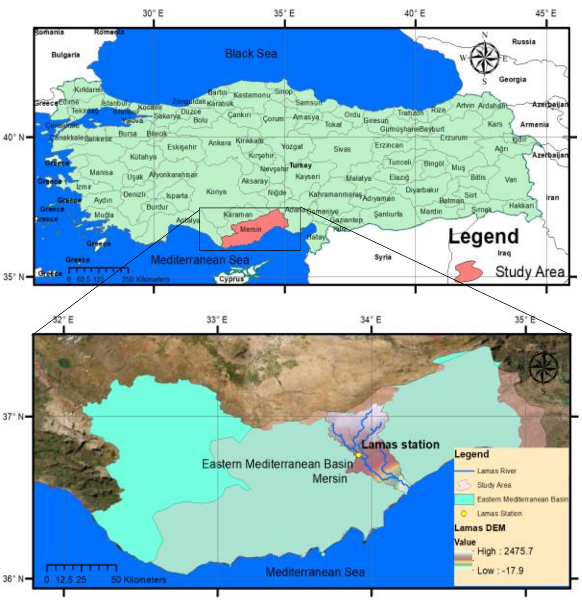


**Figure 1.** Study Area

### 2.2. HEC-RAS 2D

HEC-RAS is a program that can model 2D flow developed by the United States Army Corps of Engineers. HEC-RAS models the flood flow using full 2D Saint Venant equations and 2D diffusion wave equations (Quiroga et al. 2016).

$$\frac{\partial \zeta}{\partial t}+\frac{\partial p}{\partial x}+\frac{\partial q}{\partial y}=0 \qquad (1)$$

$$\frac{\partial p}{\partial t}+\frac{\partial}{\partial x}\left(\frac{p^2}{h}\right)+\frac{\partial}{\partial y}\left(\frac{pq}{h}\right)=\frac{n^2 pg\sqrt{p^2+q^2}}{h^2}-gh\frac{\partial \zeta}{\partial x}+pf+\frac{\partial}{\rho\partial x}(h\tau_{xx})+\frac{\partial}{\rho\partial y}(h\tau_{xy}) \qquad (2)$$

$$\frac{\partial q}{\partial t}+\frac{\partial}{\partial y}\left(\frac{q^2}{h}\right)+\frac{\partial}{\partial x}\left(\frac{pq}{h}\right)= \frac{n^2 qg\sqrt{p^2+q^2}}{h^2}-gh\frac{\partial \zeta}{\partial y}+qf+\frac{\partial}{\rho\partial y}(h\tau_{yy})+\frac{\partial}{\rho\partial x}(h\tau_{xy}) \qquad (3)$$

Where h is the water depth in meters, p and q represents the specific flow in the x and y directions (m$^2$/s), ζ is the water surface elevation (m), g is the acceleration due to gravity (m/s$^2$), n is the Manning friction coefficient, ρ is the density of water (kg/m$^3$), $\tau_{xx}$, $\tau_{yy}$ and $\tau_{xy}$ are components of effective shear stress and f is the Coriolis effect (Kamboh et al. 2016).

## 3. RESULTS

Flood modeling includes several processes. Modeling requires a digital elevation model, flow rates calculated for different return times of the Lamas river, baseline map of the region and Manning friction coefficients. In the study, the digital elevation model was obtained from the General Directorate of State Hydraulic Works (Figure 2).

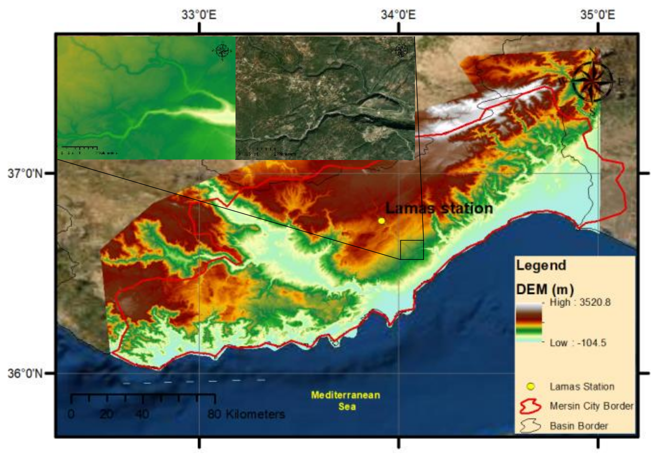


**Figure 2.** Digital Elevation Model (DEM)

The resolution of the DEM is 10 meters (Fig. 1). Flow networks and basin boundaries have been obtained using ArcGIS-Hydrology tools. For detailed information, the proposed study can be examined (Çay et al. 2018). Flood return periods are determined according to statistical and deterministic methods. In this study, flood return periods were obtained from the Eastern Mediterranean Flood Management Plan. According to this report, the study area is in flood risk areas (SYGM 2019). Flood return periods are given in Table 1.

**Table 1.** Flood values of different return periods of Lamas River.

| **Return period** | $Q_{50}$ | $Q_{100}$ | $Q_{500}$ |
|---|---|---|---|
| **Flood ($m^3/s$)** | 29.1 | 36.3 | 51.5 |

Manning friction coefficients were taken as 0.04 as an average value in the study. The distribution area ($km^2$) in the study area of $Q_{50}$, $Q_{100}$ and $Q_{500}$ return periods is given in Table 2. Flood modeling was carried out in the HEC-RAS 2D program using 25 meters of calculation areas (mesh).

**Table 2.** Flood areas

| **Return period** | $Q_{50}$ | $Q_{100}$ | $Q_{500}$ |
|---|---|---|---|
| **Area ($km^2$)** | 3.46 | 3.57 | 3.82 |

According to Table 2, an important area (with 3.46 $km^2$) is affected in modeling the $Q_{50}$ flow rate. As a percentage, the $Q_{50}$ flow rate constitutes 96% of the $Q_{100}$ flow rate and 90.5% of the $Q_{500}$ flow rate. The maps of floods in the study area are shown in Figures 3-5.

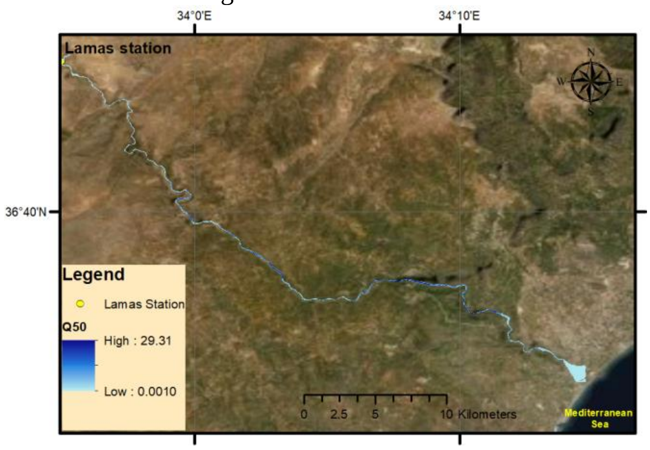


**Figure 3.** Flood propagation map for $Q_{50}$

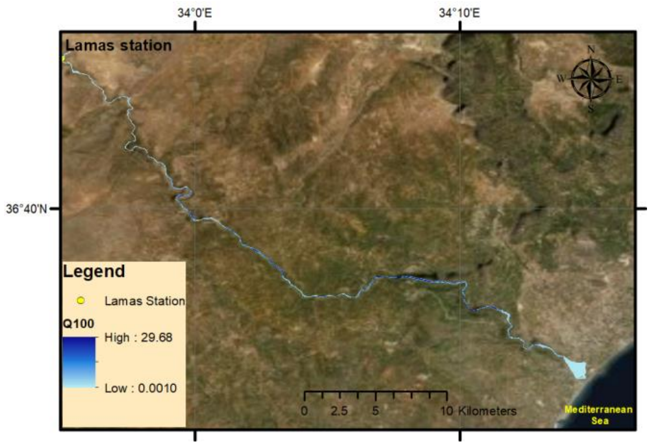


**Figure 4.** Flood propagation map for $Q_{100}$

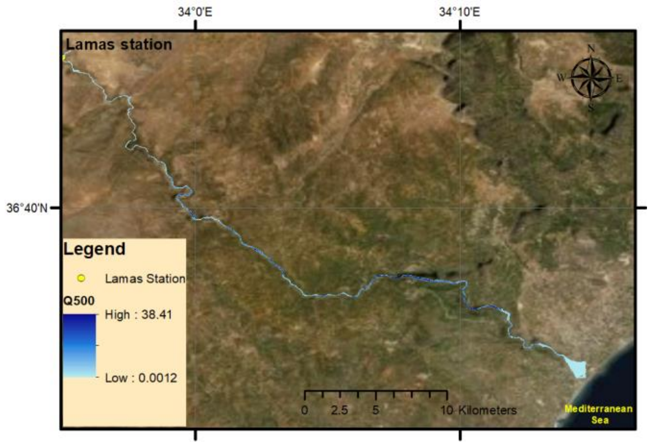


**Figure 5.** Flood propagation map for $Q_{500}$

When Figure 3-4 is examined, it is seen that the flood flow rate with 50 years and larger flood flow rates are overflowing from the river bed. Especially towards the downstream part, the right and left sides of the study area are inundated. Although the river sections are sufficient in the upstream sections, the river sections are insufficient in the downstream section. In the HEC-RAS 2D modeling, it is seen that the flow cannot follow the curves of the river downstream. As a result, water heights of up to 1-1.5 meters can be seen on the right and left sides of the river. These overflows are more common in the region to the east of the river. The reason for this situation is that the eastern region is located at a lower elevation. Besides, the flood spread could not pass to the Mediterranean from the highway between Mersin and Antalya and caused pooling in the downstream region.

## 4. DISCUSSION

Lamas river, which is the study area, is an important region that can be affected by floods according to the basin management plan. In the related plan, the Lamas river was studied together with the Sulukluk river and only in the downstream region. In this study, only the effect of the Lamas river was investigated in upstream and downstream regions. Thus, the model used was studied for the first time in the region. The results obtained are compatible and supportive of the plan. In the report, it was stated that all greenhouse areas could be submerged and the highway passing through the region could act as a set, causing high water depths in the greenhouse area behind it (Figure 6).

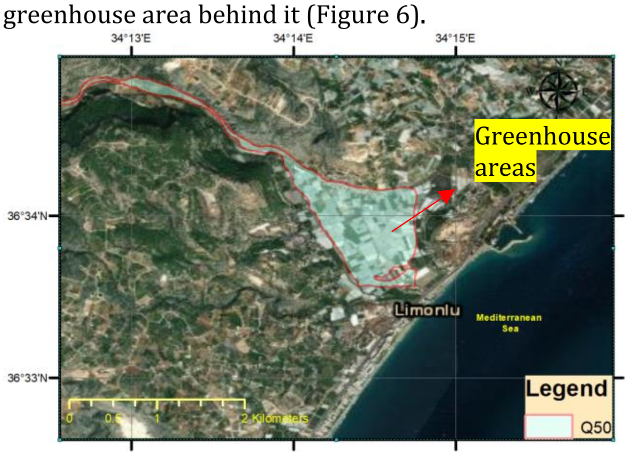


**Figure 6.** The greenhouse area affected by the flood

## 5. CONCLUSION

In this study, 3 different ($Q_{50}$, $Q_{100}$ and $Q_{500}$) flood return period Mersin/Lamas river were modeled with the HEC-RAS 2D package program that can perform 2-dimensional flood modeling. The height model in the analysis was obtained from the General Directorate of State Hydraulic Works. Food return periods were taken from the basin management plan. In the modeling, the constant 0.04 Manning friction coefficient was defined on 25-meter meshes. After hydraulic calculations were made in HEC-RAS, all results data were brought together in ArcGIS and flood propagation maps were created.

As a result of the modeling, it was determined that the area located in the downstream part of the Lamas river after the $Q_{50}$ flow rate was significantly affected by the flood. In the Mediterranean Region, regulations that can carry at least $Q_{100}$ flood flow rates should be made in urban areas. Water heights of up to 1.5 meters were determined in the downstream parts of the study area. Cross-section arrangements should be made that can carry the waters of this height. Besides, it is suggested that the pooling that occurs in the Mersin-Antalya highway region can be reduced with new channels that can be opened on this road.

## ACKNOWLEDGEMENT

The authors thank KTO Karatay University, Mersin University, General Directorate of State Hydraulic Works, and their staff for all their support.

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